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Community vulnerability assessment index for flood prone savannah agro-ecological zone: A case study of Wa West District, Ghana

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ABSTRACT

The savannah regions of Northern Ghana are characterized by smallholder farming systems and high levels of poverty. Over the past two decades, communities in the regions have become more prone to climate and human-induced disasters in the form of annual floods and droughts. This study evaluates the degree and magnitude of vulnerability in four communities subjected to similar climate change induced flood events and propose intervention options. The study employs rural participatory research approaches in developing four vulnerability categories namely socio-economic, ecological, engineering and political; which were used to develop indicators that aided the calculation of total community vulnerability index for each community. The findings indicate that the state of a community's vulnerability to flood is a composite effect of the four vulnerability index categories which may act independently or concurrently to produce the net effect. Based on a synthesis of total vulnerability obtained in each community, Baleufili was found to be the least vulnerable to flood due to its high scores in engineering, socio-economic and political vulnerability indicators. Baleufili and Bankpama were the most ecologically vulnerable communities. The selection of vulnerability index categories and associated indicators were grounded in specific local peculiarities that evolved out of engagement with community stakeholders and expert knowledge of the socioecological landscape. Thus, the Total Community Vulnerability Assessment Framework (TCVAF) provides an effective decision support for identifying communities' vulnerability status and help to design both short and long term interventions options that are community specific as a way of enhancing their coping and adaptive capacity to disasters.

1. Introduction

Increasing trends and exposure to disasters driven largely by human activities across the globe have given society cause to worry. Over the past decades, issues of human-induced climate change related disasters have become a major area of concern especially in the global south where human communities and ecosystems are known to be more vulnerable. It has therefore become essential to assess human vulnerability to disasters in the context of climate change as a way of devising practical and sustainable intervention options.

Vulnerability has emerged as useful and hotly contested concept for understanding, measuring and evaluating the conditions of people to disasters. Resilience and vulnerability have ambivalent characteristics especially in cases where resilient systems are often supposed to be less vulnerable compare to non-resilient systems (Walker et al., 2004). The ambivalent nature of vulnerability and resilience concepts does not make them contradictory or show symmetrical comparisons because vulnerability seems largely to imply an individual or societys' inability to cope and

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resilience seems to broadly imply an ability to cope in the face of stresses and shocks (Levina and Tirpack, 2006). Ordinarily, “vulnerability” is used to refer to the capacity to be wounded, i.e., the degree to which a system is likely to experience harm due to exposure to a hazard (Turner et al., 2003). In broad terms, vulnerability has two schools of thought. The natural hazard school of thought focuses on risk of exposure of an ecosystem to a hazard and the human ecology and political economy school of thought emphasizes exposure of social unit to the structures and institutions that govern human lives (Vincent, 2004). The Intergovernmental Panel on Climate Change (IPCC) defines climate-related vulnerability as the “degree to which a system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extreme weather conditions” (IPCC, 2007). The IPCC emphasizes that a comprehensive assessment and understanding of vulnerability of an area is critical for developing adaptive measures and resilience building (IPCC, 2001, 2007). Thus, there is the need to assess the degree of community vulnerability.

This paper views the concept of community vulnerability as analytically embracing ecological, engineering/physical, political and socio-economic capacities (Folke, 2006). Moser (1998) in contributing to the vulnerability discourse contends that environmental changes threatening human welfare could be attributed to the existing ecological, economic, social or political conditions. These changes may take the form of sudden shocks, long-term trends or seasonal cycles. Ecological vulnerability measures the susceptibility of a natural system to adverse impacts from hazards (NOAA, 1999; De Lange et al., 2010). Socio-economic vulnerability is the state of individuals, of groups, of communities defined in terms of their ability to cope with and adapt to any external stress placed on their livelihoods and well-being (Adger and Kelly, 1999). In this sense, socio-economic vulnerability is the inability of people, organizations, and societies to withstand adverse impacts from multiple stressors to which they are exposed to (Eidsvig et al., 2011). Turner and Dumas (2013), define political vulnerability as the lack of institutional support and the right to participate in decision making process at any level i.e. local, regional, national or international. Engineering vulnerability assesses how prone a system's ability to return to steady state is; after disturbance event that affect e.g. infrastructure, land use, soil composition and the agro-biodiversity in a community.

It is possible to identify and develop indicators at specific localities to assess vulnerability based on the political, socio-economic, engineering and ecological settings of localities. Vincent (2004) used social vulnerability index to empirically assess relative levels of climate change-induced variations in water availability across countries in Africa. Antwi-Agyei et al. (2011) assessed the economic vulnerability for the whole of Ghana using crop yield sensitivity index and drought sensitivity index. In Mozambique, Hahn et al. (2009) used the livelihood vulnerability index (LVI) approach to estimate and compare the economic vulnerability caused by climate change in two local communities. According to the IPCC (2001), the integration of different variables for index computation makes community vulnerability assessment holistic. Ghana has experienced seven major floods between 1995 and 2010, with devastating consequences (Kankam-Yeboah et al., 2010). In Northern Ghana, the floods of 2007 and 2010 were the most devastating in recent years. Flood from 2007 torrential rains (in excess of 30 mm) rendered over 330,000 people homeless and severely damaged farmlands, livestock, human lives and infrastructure (NADMO, 2010). Taking a cue from these, the paper presents field-based evidence of flood vulnerability assessment in four neighboring communities subjected to similar climate change induced disaster in the Savannah agro-ecological zone of Northern Ghana. The general aim of the study was to assess the composite community vulnerability to flood related events induced by climate change. We hypothesized that the state of a community's vulnerability to flood is a composite effect of its ecological, socio-economic, engineering and political setting acting independently and/or interrelatedly. In examining this hypothesis the study was guided by the following questions:

i. To what extent can vulnerability indicators reveal the state of community vulnerability in flood prone areas?
ii. What is the ecological, socio-economic, engineering and political vulnerability status of the study communities?
iii. How does the state of a community’s total vulnerability inform the adoption of intervention options?

1.1. *Conceptual framework for Community Vulnerability Assessment*

In order to assess the level of communities' vulnerability to predictable and unpredictable seasonal shocks such as floods induced by climatic changes, our study developed an analytical tool based on complex interaction of human and natural indicators under what we call Total Community Vulnerability Assessment Framework (TCVAF). Exposure to predictable and unpredictable shocks such as floods induced by climatic changes in recent years is driving a more complex interaction along physical, natural, political and socio-economic levels that produces unpredictable outcomes. The degree and magnitude of these events make many communities and households more vulnerable. Over the years, the livelihood framework analyses have been central in development studies; allowing researchers to understand the livelihoods of the poor.

The development of the Total Community Vulnerability Assessment Framework by the research team was guided by existing theoretical concepts in the vulnerability and resilience discourse. Additionally, practical knowledge of the physical, socio-economic, ecological and political conditions within the context of the study area were relied upon.

The framework argues that, state of communities' vulnerability is determined by the complex interaction of human and natural indicators including, population density, social network and capital, landscape diversity and landscape elevation (Fig. 1).

By emphasizing the state of socioeconomic, ecological, political and engineering conditions of a community through the lenses of closely linked anthropogenic and naturally driven indicators; we enhance the conceptual understanding of vulnerability with the aid of verifiable and place-specific data. According to Eriksen and Kelly (2007) noted, lack of clear theoretical and conceptual framework for the selection of natural or human indicators has hindered the robustness, transparency and policy relevance of studies that attempted to assess the communities' vulnerability. The indicators being proposed in this study, though not exhaustive are deemed adequate for operationalizing the concept of vulnerability. As Eriksen and Kelly (2007), the selection of indicators and the repercussions of choosing particular indicators have been have been a debatable issue. In our study, the selected indicators are expected to reveal the nature and magnitude of inherent differences and similarities of communities and thier implications on vulnerability. It must be said that the idea of quantifying vulnerability could be somewhat problematic (Adger and Kelly, 1999) hence the need to use a framework that considers fundamental component indicators and key activities that can give dependable output.

The framework shows a vulnerability context of floods arising from irregularity in rainfall and exposure to flood. Thus, a community's vulnerability context is a function of a web of interactions or interdependence among vulnerability index categories: physical/engineering, socio-economic, natural/ecological and political/institutional systems. A set of indicators for each vulnerability

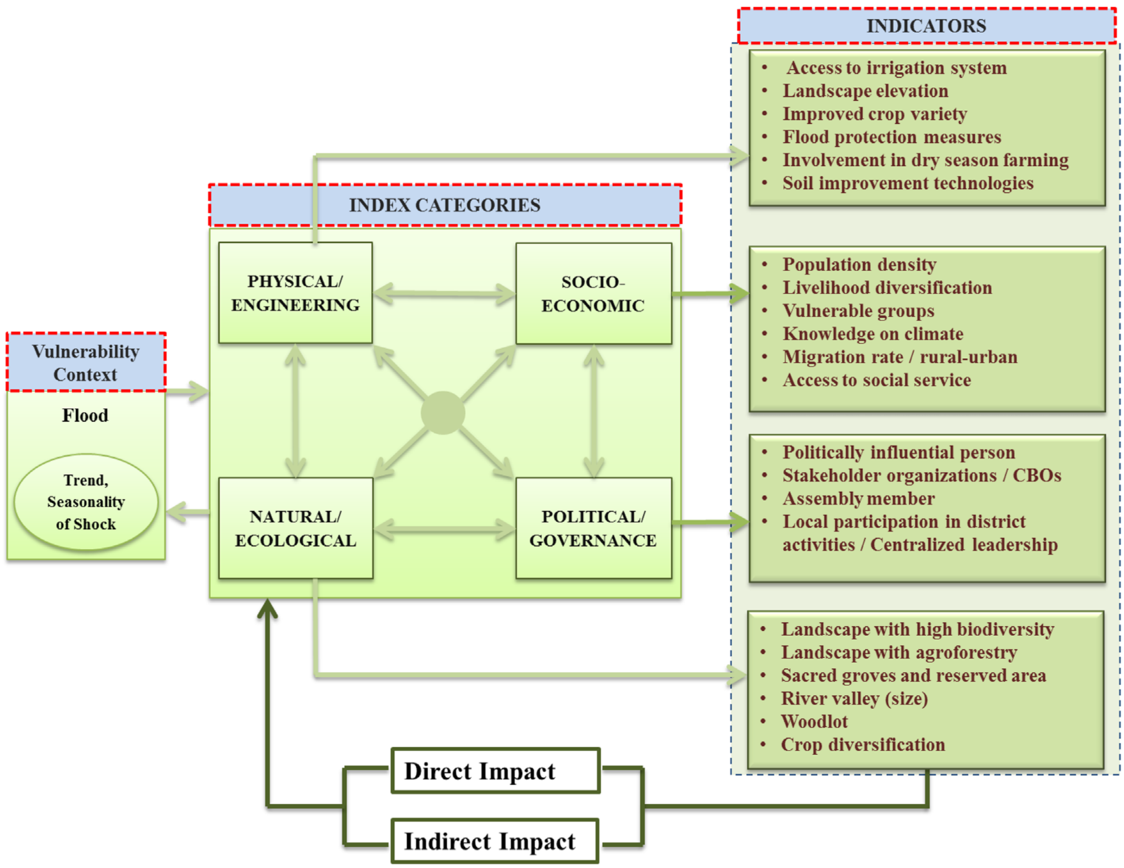


Fig. 1. Total Community Vulnerability Assessment Framework (TCVAF).

index category is expected to impact on a community either directly or indirectly in a synergistic manner to produce a specific vulnerability outcome.

In this study, we identify the various categories of vulnerability at household and community levels in the face of flood as natural and human-induced disaster. Contextually, the measure and degree of vulnerability to flood is contingent on the strength or weakness of different aspects or components of the community. To be able to holistically analyze the vulnerability of communities to flood events, we categorize vulnerability into physical or engineering, socio-economic, ecological or natural and political. We argue that the four vulnerability index categories are closely connected. The individual indices shown in Fig. 1 are known to produce various outcomes at different rates and magnitudes. For instance the outcome of socio-economic vulnerability in the context of this framework and in reference to existing livelihood strategies could be akin to the population density of community, migration rate and trends, nature of vulnerable groups (children, disabled), knowledge on climate change, access to social services and income sources. Results from individual indices show the strength or weakness of a community in dealing with flood related disasters. Again, the interrelatedness of each category of vulnerability comes to play in defining final vulnerability outcome. A community might be less vulnerable in one or two categories but its total vulnerability might be high. Against this backdrop, the total vulnerability status of a community is best measured from a summation of the individual indices which are also calculated based on the aggregation of assigned score from the outcomes under each index. Thus, Total Community Vulnerability (TCV) should sum up engineering/physical, socio-economic, natural/ecological and political/governance.

The TCV tells of the areas of livelihood that communities need to improve or maintain in an attempt to become sustainable and more resilient to recurring incidence of floods. Again, it can be a good indicator for generating intervention options for different communities in order to avoid generalization and duplication of intervention option as has often been the case with most community intervention options especially from central government.

2. Materials and methods

2.1. Study area

2.1.1. Physical geography of the study area

The study area, Wa West District, is one of the eleven districts making up the Upper West Region of Ghana. The district lies between longitudes 9°40′N and 10°10′N and latitudes 2°20W and 2°50′W. The climate of the district is semi-arid with two major seasons namely the dry season (late October–April) and the wet season (May–early October). There are also two major air masses that blow across the area namely the northeast trade winds (associated with the dry seasons) and the south west monsoon winds (associated with rainy seasons). Annual rainfall ranges from 750 mm to 1100 mm, whereas temperature ranges between 15 °C at night during the harmattan period and 40 °C at day during the hot season especially in March (GMet, 2012).

The vegetation of the district is guinea savannah grassland characterized by shrubs, grass and scattered drought resistant trees of economic importance. The most common tree species are dawadawa (*Parkia biglobosa*), Shea (*Vitellaria paradoxa*), mango (*Mangifera indica*), Kapok (*Ceiba pentandra*), Baobab (*Adansonia dipitata*) and neem trees. There are several other trees which provide households' requirements for fire wood, charcoal, construction of houses, craft works, and fencing of gardens as well as that of cattle kraal.

2.1.2. Socio-economic characteristics

Wa West District has a total population of about 81,348 representing approximately 11.57% of the total population of the Upper West region, with a population density of 44 people per km^2 (GSS, 2013). The most common economic activity in the district is agriculture accounting for 80% of jobs. Agricultural activities are usually on small scale including cultivation of crops (e.g. maize, groundnut, sorghum, millet and rice) and rearing of animals (cattle, sheep, goats, pigs and poultry). Female dominated economic activities include shea butter processing, dawadawa processing, fuel wood gathering, and petty trade. Most of these activities are seasonal due to raw materials shortage. The availability of water bodies also provides inland fishing opportunities particularly for the males.

Drastic change in climate has introduced perennial floods and severe droughts that adversely affect agricultural production especially food crops in the area. Agriculture production is further constrained by the erratic rainfall pattern as well as the declining duration of the raining season in the district.

2.2. Data collection approach

2.2.1. Selection of study community and households interviews

The four communities; Chietanga, Baleufili, Bamkpama and Zowayeli were selected due to their peculiar experience of flood annually as well as their proximity to the Black Volta River.

In our assessment, a probability proportional to size (PPS) sampling procedure similar to that described by Yansaneh (2005) was applied to determine the sample size for each community. Thus, the sample of each community was selected based on the number of households in the community proportional to the total number of households of the four communities. This procedure was preferred as it minimizes inaccuracies due to growth or shrinkage of some communities. Furthermore when the PPS is combined with appropriate sub-sampling fraction it can yield overall self-weighting. Besides, it is more reliable for comparative analysis. The sampling frame consists of total number of households in all four communities. A list of all households in each community was obtained from records of an earlier phase of the "*Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa (CECAR Africa)* project".[1] Using the proportional sampling technique, 40% of the total households (i.e. 104 households) was taken as the sample size from which the sample of individual communities were obtained. Table 1 presents a summary of the sampling frame and sample size.

Table 1
Household sampling frame and size in study communities.

Name of community	Number of households per community	Number of sampled households based on PPS
Chietanga	46	19
Baleufili	105	42
Bamkpama	79	32
Zowayeli	28	11
Total	258	104

Source: Field Survey, 2013.

Households in selected communities formed the basic unit for the field data collection for the study. In all the sampled communities, the head of household was the focal person, however, where the partner is available, they were also interviewed. For the purpose of uniformity and also to take care of local peculiar arrangements, a house compound which may consist of one or more housing unit but under the headship of one family head was defined as a household and used as a unit of analysis. The communities surveyed were male dominated societies with mostly male headed households, hence the dominance of males in the interviews. However, key informants interviews were organized in each community to identify female headed households which were factored into the house compound selection. A standardized survey questionnaire of both closed and open ended questions were administered to the respondents at the household level. The use of questionnaires provided a direct way of eliciting information from informants which were then used for analysis (Wisker, 2008). The household surveys explored the demographic characteristics of the house compound, the relationship of the compound with the wider community in terms of access to common resources and engagement with external actors. Hay (2008) argues that interviews enable researchers to have access to information about events, opinions, and experiences. The GPS location of each house compound was recorded and this aided the community asset mapping.

[1] A five year collaborative research with Ghanaian and Japanese universities aimed at enhancing resilience amongst agro-pastoral and natural resource dependent communities in Northern Ghana.

2.2.2. Focus group discussions

In each community, two focus group discussions were conducted to compliment the household survey. The focus group discussions were undertaken with a section of adult males (15) and females (16). A discussion protocol was used to moderate the focus group discussion though the questions were varied to reflect the pattern of the discussion. Although the data were collected using discussion protocol, the results were collated and grouped. The discussion therefore captures the opinions of the group and not individuals. Also, the results of the focus group discussions were used to determine the factors and vulnerability rating. The group discussion enabled the study to gain more insight and complimented the use of the household survey in taking information on the generality of issues within the agro-ecological system and vulnerability indicators. This tool was effective in generating the participation of respondents to enhance the researcher-target group interaction and ensured that there was free flow of otherwise unsolicited information that became important for the study (Gyasi and Enu-Kwesi, 1997).

2.2.3. Transect walk and key informant interviews

Transect walks were aimed at accessing and mapping community assets such as community centers, sacred groves, health and sanitation posts, rivers, irrigation facilities, farmlands, woodlots, river valleys and areas vulnerable to flood events. Knowledgeable community members designated by chief and elders in target communities led the team. With the aid of GPS, coordinates of community features were mapped. Casual observation and key informant interviews within the communities were also done to identify discrepancies. Photographs were also taken to provide a visual impression of community resources and areas of interest. At the end of the walk, brainstorming sessions were held with the key informants comprising mainly the chief and his elders and assemblymen to verify the results obtained. Photographs of the verified communities' asset maps were taken. The results of the walk provided the baseline data for community mapping and further analyses.

3. Theory/calculation

3.1. Development of engineering, socio-economic, ecological, and *political vulnerability index for community survey*

To assess household and community level vulnerability, the study identified key indicators under four main vulnerability index categories ; engineering, socio-economic, ecological and political. The selection of indicators was a multistage process done as part of the broader study under the CECAR Africa project as reported by Antwi et al. (2014). The first process involved stakeholders consultation, followed by expert evaluation and finally stakeholders and expert ranking. Several indicators were initially identified from this process by stakeholders and evaluated by the experts. In the final stage both stakeholders and experts arrived at the six broad relevant indicators applicable at the local level. The use of many indicators e.g. more than six indicators could make it difficult to notice which indicators are more crucial in the final community vulnerability assessment. This paper attempts to test the relevant vulnerability indicators developed by both experts and local community stakeholders as reported by Antwi et al. (2014).

Under each vulnerability index category, several indicators were identified, however, the top six relevant indicators were listed and used. The six indicators for each vulnerability index category were arrived at by obtaining a detailed ecological knowledge of the community through transect walk and engagement with stakeholder groups at the community, Through focus group discussions, the various dynamic processes which affect community vulnerability levels and other inherent differences in these processes were identified and noted. Table 2 provides information on the vulnerability index category used and description of indicators. To measure the level of vulnerability under each indicator, ratings of low, moderate and high were assigned based on stakeholder perceived contribution. The ordinal vulnerability rankings of low, moderate and high were reclassified into numeric scores of 1, 2 and 3 respectively. In arriving at the vulnerability score, the number of respondents in each community was calculated as a percentage of the total sample size. Thus in a community, a vulnerability indicator score of 0–33.33% was considered highly vulnerable and assigned a value of (3); 33.34–66.66% moderately vulnerable and assigned a value of (2) and 66.67–100%

Table 2
Description of key indicators from household survey and project metrics.
Source: Field Survey, 2012; 2013.

Vulnerability category	Indicator	Indicator description
Engineering	Access to irrigation system	Access to irrigation mostly in the form of small dams including dug outs in Northern Ghana allows a community to plant in the dry and wet seasons.
	Landscape elevation	Landscape elevation in relation to the location of a community to a major river body can give a proxy indicator of the vulnerability to flooding. In the case of Northern Ghana, the elevation of a community in relation to the Volta river is very important.
	Improved crop variety	Improved crop variety which could mean early maturing variety, late maturing variety, drought, high yielding or pest resistant variety.
	Access to portable drinking water	Potable drinking water in the context of Northern Ghana could mean access to protected dug well, borehole, protected spring and rain water collection.
	Involvement in dry season farming	Involvement in dry season farming by a community either lying closer to a water body e.g. the Volta lake or having access to a small dug out community dam.
	Soil improvement technologies	Use of soil improvement technologies include all organic and inorganic amendments such as chemical fertilizer available to community and applied to the soil.
Socio-economic	Total population/population density	The total population in relation to land size. In Northern Ghana, population densities between 10 and 50 p/km^2 are characterized by rapid natural resource depletion and agroecological degradation (Songsore, 2011).
	Livelihood diversification (off-farm income source)	This involves availability of other income generating activities to supplement farming. It includes artisanal skills or trading, off farm employment in local cottage industry etc.
	Vulnerable groups (women, children, physically challenge invalids)	Vulnerable groups who may need the assistance or depend on others in case possible disaster risks.
	Knowledge on climate	Ability to discern local changing environmental and climatic conditions and to adopt measures to counteract same.
	Migration rate/rural–urban migration	Evidence of migration in the community, the sex of migrants, destination areas, engagement with household back home e.g. through remittances.
	Access to social services	Ease of access to health facility such as a hospital, clinic, a CHIPS compound within community or in accessible distance/location.
Ecological	Landscape with high biodiversity	General evidence of high floral and faunal diversity within a community either domesticated or naturally regenerating.
	Landscape with agroforestry	Presence of high density of domesticated or naturally regenerating tree species in farm lands.
	Sacred groves and reserved area	Maintenance of ecological sites of importance either socio-culturally or ecologically.
	River valley (size)	Size and availability of river valleys used for crop cultivation (largely rice) in relation to other communities or the number of households.
	Woodlot	Presence of domesticated wood species in designated places and used to support the wood fuel needs of a community.
	Crop diversification	Availability of different crop types including cash crops and food crops that satisfy both household consumption and market needs.
Political	Politically influential person	Availability of a regional or national political figure or business man hailing/residing in the community.
	Community Stakeholder Organizations / CBOs	Existence of locally based advocacy organization or presence of an external advocacy group working in the community.
	Assembly member	Availability of an assemblyman residing in the community.
	Local participation in district activities	Level of household level participation, advocacy and interests in district level political activities.

was least vulnerable hence a value of (1). As each indicator was seen as having either direct or indirect impact on community vulnerability, impact factors; direct or indirect, were assigned to each indicator as follows; direct impact=1 and indirect impact = 0.5 The level of vulnerability for each category (i.e. ecological, socio-economic, engineering and political) was calculated using the Eq. (1) below.

$$\text{Vulnerability} = \sum_{k=0} ka^{n-k} \tag{1}$$

Eq. (1) represents the total vulnerability category to floods, (idx) represents the vulnerability indicator scores, n=sample size, a=impact factor (direct impact=1; indirect impact=0.5) and k=2 ((1+2+3)/3)). Total community vulnerability (TCV) was estimated from sum of ecological, social, engineering and economic vulnerability as shown in Eq (2).

$$(\text{TCV}) = \sum (\text{TCV ecological vulnerability, vulnerability social; vulnerability economic}) \tag{2}$$

4. Results

4.1. Demographic profile of respondents

Table 3 shows the summary of the demographic profile of sampled respondents. The gender profile of the four study communities shows majority of respondents, more than 71% were male headed households. The dominance of male respondents is typical of the socio-cultural norms and practices in most Ghanaian societies that have high male headed households. All the communities also had low level of formal education. An overwhelming average of 90% had no formal education while 10% had primary education in most cases.

The average household size of the communities fall between 6 and 10 people. Large household size in most rural communities in Northern Ghana is seen as a source of pride as well as an economic asset. The population is fairly young as majority of respondents were between 21 and 60 years. These demographic trends are largely a reflection of trends in the area as reported during the 2010 Population and Housing Census (GSS, 2013).

An analysis of the alternative source of livelihood reveals a marked difference between Baluefili and the other three communities. Whilst majority of respondents in the other three communities did not have any other source of livelihood aside farming activities (Table 3), about 33% of households in Baleufili indicated that they have other sources of livelihood beyond farming. Some of the livelihood options mentioned in Baleufili include driving, trading, fishing and engagement in construction works.

4.2. Community vulnerability Scores

For each of the four communities, a vulnerability score was obtained for each of the vulnerability indices used. Table 4 shows the vulnerability score of key vulnerability indicators and their impact on community. Based on the severity of a particular index on communities (direct or indirect), impact factors were assigned as shown in Table 4. Individual or single factor vulnerability scores were 1, 2 and 3, indicating low, moderate and high vulnerability respectively. The cumulative impact of indicators in each vulnerability index category was used to assess the community vulnerability profile in each vulnerability index category as provided in Section 3.1.

Table 3
Demographic profile of respondents in study area.
Source: Field Survey, 2013.

Characteristic	Percentage of respondents in study community			
	Baleufili (n=42)	**Bamkpama (n=32)**	**Chietanga (n=19)**	**Zowayeli (n=11)**
Gender				
• Male	76.2	71.9	78.9	72.7
• Female	23.8	28.1	21.1	27.3
Education Level				
• No Education	69.0	78.1	89.5	90.9
• Primary	16.7	6.3	5.3	9.1
• JHS	9.5	15.6	5.3	0.0
• MSLC/SHS	4.8	0.0	0.0	0.0
Household size				
• 0–5	14.3	9.4	21.1	18.2
• 6–10	73.8	75.0	63.2	54.5
• 11+	11.9	15.6	15.8	27.3
Age				
• Under 20	14.3	9.4	10.5	9.1
• 21–40	38.1	43.8	47.4	36.4
• 41–60	40.5	31.3	36.8	45.5
• 61 and above	7.1	15.6	0.0	9.1
Alternative source of Livelihood				
• Yes	33.3	18.8	15.8	18.2
• No	66.7	81.3	84.2	81.8

4.3. Community vulnerability profile estimated from CVI

4.3.1. State of communities engineering vulnerability

Regarding engineering vulnerability, a synthesis of the results based on six indicators shows that Baluefili is the least vulnerable. It had a total score of 20 followed by Chietanga (26), Zowayeli (31) and Bamkpama (36) as shown in Fig. 2. Thus, the results indicate that Baleufili is more resilient with Bamkpama being the least resilient. Baleufili has effective irrigation systems. Ironically, the proximity of the other three communities to the Black Volta River has not enhanced their ability to engage in all-year farming due to general lack of irrigation systems.

Chietanga, which is the second least vulnerable community, recorded medium (4) score for involvement in dry season farming and use of soil improvement technologies. Zowayeli on the other hand scored only medium (4) in the area of soil improvement technologies which makes it the second most vulnerable community. The closeness of the three communities to the Black Volta River suggest they experience frequent and higher magnitude of flooding either from occasional spillage of the Bagre dam and or torrential rain falls as compared to Baleufili which is less likely to experience flooding because of its location in relation to the Black Volta River.

4.3.2. State of communities-socio-economic vulnerability

The result of the socio-economic vulnerability assessment is shown in Fig. 3. Baleufili and Zowayeli are the least socio-economically vulnerable communities with minimal rural-urban migration, good livelihood diversification (1) as well as low population density (4). They both have total community vulnerability index score of 23. On the other hand, Chietanga is more vulnerable followed by Bamkpama which is the most vulnerable. The two communities had a vulnerability score of 31 and 36 respectively.

Table 4
Vulnerability score of key vulnerability indicators and their impact on community.

Vulnerability category	Indicator	Impact factor	Vulnerability score			
			Baleufili	Bamkpama	Chietanga	Zowayeli
Engineering	Access to irrigation system	1	1	3	3	3
	Landscape elevation	0.5	2	3	2	2
	Improved crop variety	1	3	3	3	3
	Flood protection measures	0.5	2	3	3	2
	Involvement in dry season farming	1	1	3	2	3
	Soil improvement technologies	1	3	3	2	2
Socio-economic	Total Population/population density	0.5	2	1	3	2
	Livelihood diversification (off-farm income source)	1	1	3	3	1
	Vulnerable groups	1	3	3	2	2
	Knowledge on climate	0.5	3	3	2	3
	Migration rate/rural–urban migration	1	2	3	3	3
	Access to social services	1	3	3	3	3
Ecological	Landscape with high biodiversity	1	3	1	2	1
	Landscape with agroforestry	1	2	3	1	2
	Sacred groves and reserved area	1	3	2	1	2
	River valley (size)	1	2	1	1	1
	Woodlot	1	1	2	2	1
	Crop diversification	1	1	3	2	3
Political	Politically Influential person	1	1	3	2	3
	Community Stakeholder Organizations/CBOs	1	1	3	2	3
	Assembly member	1	2	2	2	2
	Local participation in district activities Centralized Leadership	1	1	3	2	3

While Zowayeli community is less vulnerable with regards to climate change knowledge (score of 0.02), the opposite is true for Baleufili (score of 8.2). Chietanga reported medium (4) score for vulnerable group and knowledge on climate as far as socio-economic vulnerability is concerned. Bamkpama, the most vulnerable community on the other hand, recorded high (9) vulnerability for almost all the six indicators (Fig. 3).

4.3.3. State of communities ecological vulnerability

Fig. 4 shows the result of ecological vulnerability for the four communities. Chietanga is the least ecologically vulnerable community with a score of 15, followed by Zowayeli (20). Baleufili and Bamkpama are the most ecologically vulnerable having the same score of 28. Chietanga has large landscape with agroforestry, sacred groves and reserved area. Again, the presence of river valley, high landscape biodiversity, and existence of woodlot and crop diversification techniques were found in Chietanga. While Zowayeli is second least vulnerable, it has less crop diversity with a high vulnerability score of 9. While Baleufili and Bamkpama scored the same ecological vulnerability, there are clear differences in the mix of vulnerability indicators that combined to form the total community ecological vulnerability score. Baleufili recorded low vulnerability score (1) for crop diversification and woodlot; and medium vulnerability score (4) for landscape with agroforestry and presence of river valley. Bamkpama however recorded low vulnerability score (1) for landscape with high biodiversity and presence of river valley and medium score (4) for sacred groves and reserved area. Baleufili unlike Bamkpama was highly vulnerable with regard to landscape with high biodiversity (9) but least vulnerable with regard to crop diversification (1).

4.3.4. State of communities political vulnerability

As shown in Fig. 5, Baleufili is the least politically vulnerable community with total community vulnerability score of 7. This is followed by Chietanga with a score of 16. Bamkpama and Zowayeli are the most politically vulnerable communities with same total political vulnerability score of 31. Baleufili has politically influential persons in their community; community stakeholders and assembly members who actively participate in district governance activities. Chietanga reported medium score (4) for all the four political vulnerability indicators. However, Bamkpama and Zowayeli reported the same political vulnerability levels. Both reported high vulnerability score (9) for presence of influential persons, community stakeholders and the participation of the local people in district activities. The only influencing factor which makes these communities a little less vulnerable is the availability of assembly members in both communities.

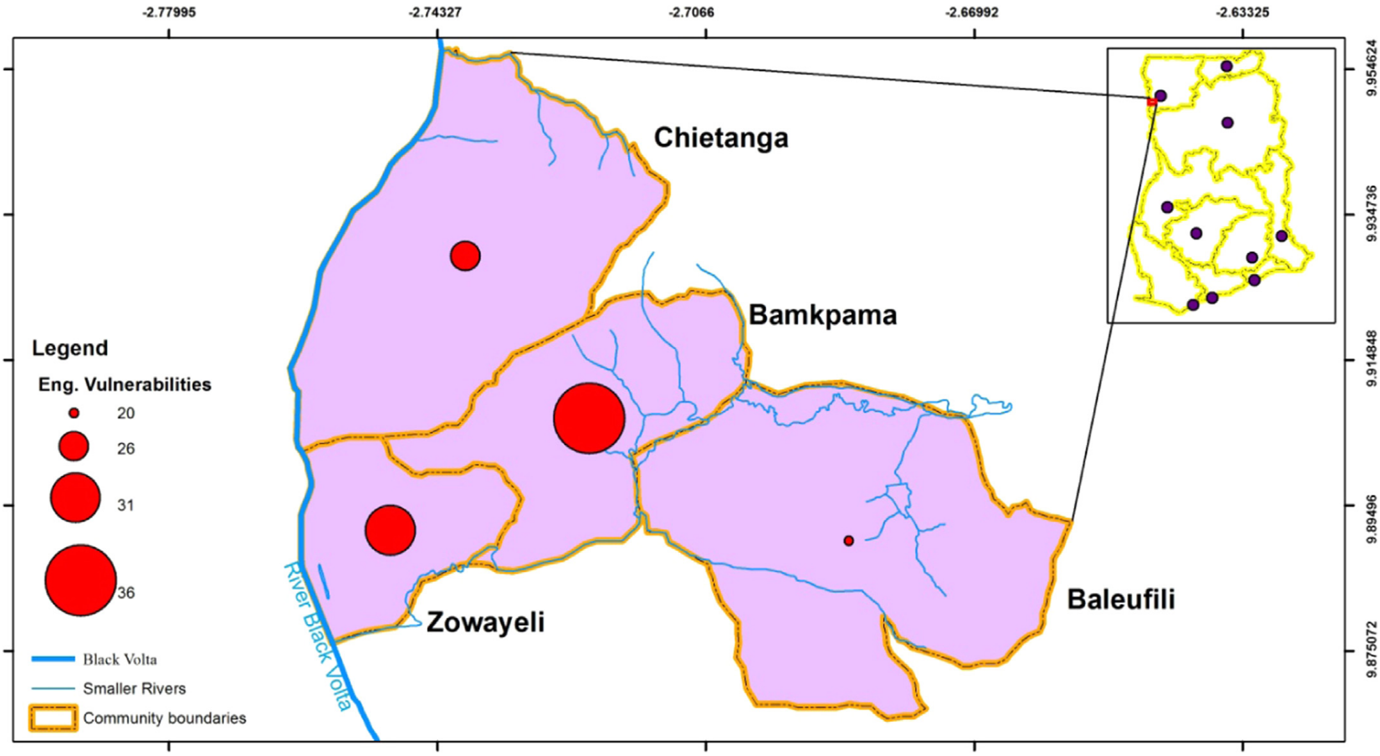
4.3.5. Total Community Vulnerability (TCV)

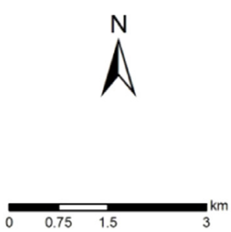
The Total Community Vulnerability (TCV) estimated provides a cumulative vulnerability score for all the vulnerability indicator factors across the study communities. Fig. 6 shows the summary TCV Index. Cumulatively, TCV shows that Baleufili is least vulnerable. The least political, socio-economic and engineering vulnerability accounts for the low TCV of Baleufili. But ecologically, Baleufili is the most vulnerable. Chietanga is ecologically the least vulnerable but most vulnerable socio-economically.

It can be observed that Baleufili is the least vulnerable to floods based on the index considered in the study. Chietanga followed suit with Zowayeli and Bamkpama coming in third and last respectively. Bamkpama performed poorly in the entire index (engineering, socio-economic, ecological and political vulnerability) which accounts for its state as the most vulnerable community studied (highest TCV). Zowayeli is highly vulnerable in the engineering and political vulnerability category.

5. Discussion

5.1. Evaluation of Total Community Vulnerability Assessment





Vulnerabil Category	Indicator	Baleufili	Bamkpama	Chietanga	Zowayeli
Engineering	Access to irrigation system	1	9	9	9
	Landscape elevation	3.64E-12	8.38E-09	3.05E-05	0.007813
	Improved crop variety	9	9	9	9
	Flood protection measures	3.64E-12	8.38E-09	6.87E-05	0.007813
	Involvement in dry season farming	1	9	4	9
	Soil improvement technologies	9	9	4	4
	Total Community Vulnerability (TCV)	**20**	**36**	**26**	**31**

Fig. 2. State of communities engineering vulnerability.

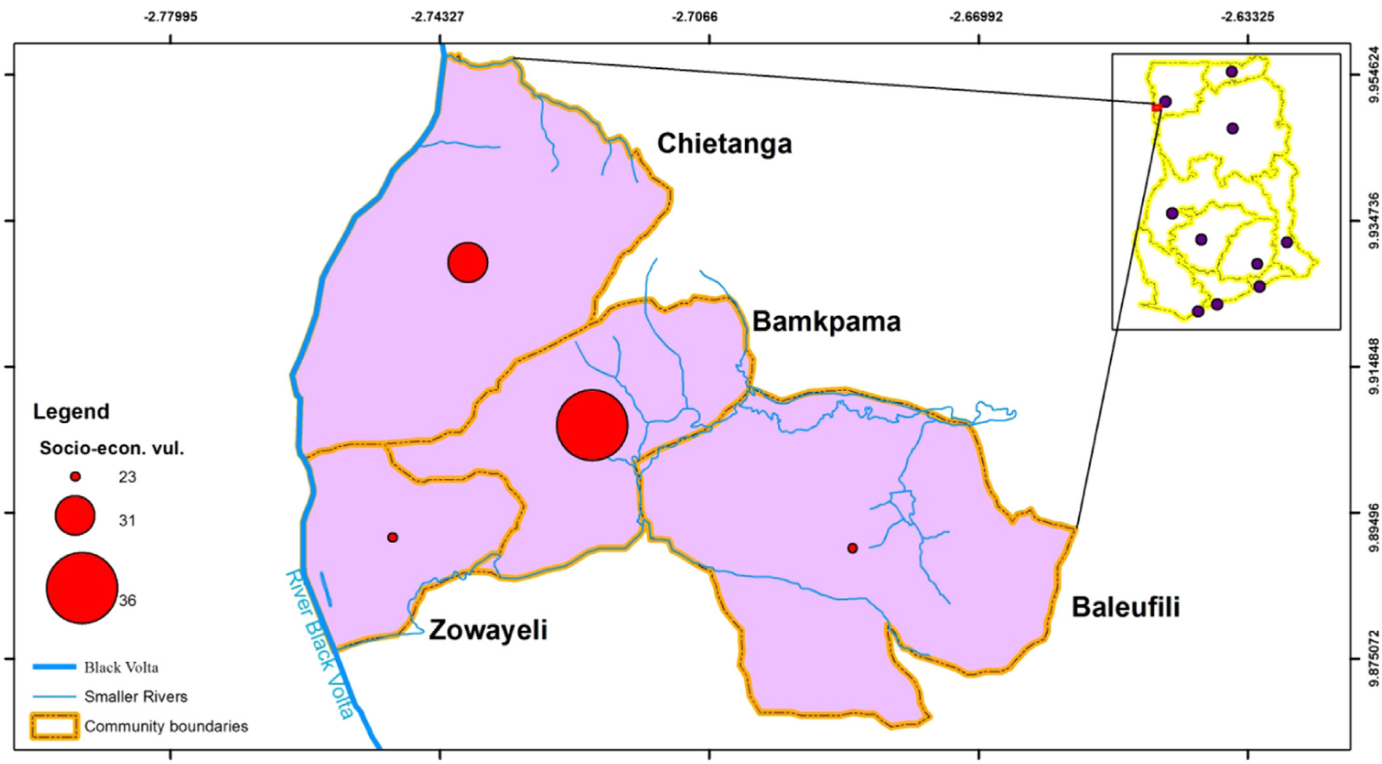
Framework (TCVAF)

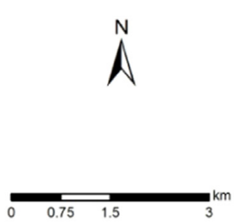
5.1.1. State of communities engineering vulnerability

In terms of engineering vulnerability, Baleufili was found to be least vulnerable due to its easy access to irrigation facilities and involvement in dry season farming using the main community dam. Chietanga is moderately vulnerable due to the lack of irrigation facilities in the community. As a result, farmers have to rely exclusively on rainfall which is mostly erratic. Though the community has rivers that it can tap into, these are seasonal and dry up during the long dry harmattan. Zowayeli and Bamkpama have very little or no access to irrigation facilities and are therefore unable to engage in active dry season farming. A study by Yahaya (2002) indicated that presence of irrigation facility in a savannah agro ecological zone does not only help in times of drought but also provides strong socio-economic gains especially to rural poor farmers whose livelihoods depend on rain-fed agriculture. Irrigation system also enhances food security and the overall resilience of a community. It is important to emphasize however that the presence of irrigation system in a savannah ecological zone can also pose undesirable results especially during flooding causing destruction of farm produce (Yahaya, 2002) if not well managed.

With regards to the communities proneness to flood owing to their elevation, the most vulnerable community is Zowayeli and the least vulnerable is Bamkpama. Though Zowayeli and Chietanga have close proximity to the Black Volta River (Fig. 2), the comparatively high vulnerability status of Zowayeli is due to the fact that its entire community viz houses and farm lands are located in low lying elevation. On the other hand, majority of the houses in Chietanga are located on a relatively higher elevation though most of the farms have close proximity to water bodies at lower elevation areas. Furthermore, Chietanga's vulnerability is linked to the rocky nature of their land where iron pans dominate as in many other areas of semi-arid Northern Ghana (Abekoe and Tiessin, 1998; Asamoah et al., 2013). The presence of iron pan in Chietanga reduces its farmland area and also limits farming activities to low lying areas susceptible to floods.

Though Baleufili is located further away from the Black Volta River, its low vulnerability status is attributed to the high elevation and presence of buildings that can withstand floods. Unlike Baleufili, most settlements in Zowayeli and Bamkpama are mud constructed houses with thatch roofing. These materials easily gets soaked up with water causing buildings to collapse easily during flooding. Although Bamkpama is located on a higher elevation, it still recorded highest engineering vulnerability (36) because of its population size in relation to its land mass. It happens to be the most densely populated community among the communities studied.





Vulnerability Category	Indicator	Baleufili	Bamkpama	Chietanga	Zowayeli
Socio-economic	Total Population / Population Density	3.64E-12	9.31E-10	6.87E-05	0.007813
	Livelihood diversification (off-farm income source)	1	9	9	1
	Vulnerable Groups (women, children, physically challenge invalids)	9	9	4	4
	Knowledge on climate	8.19E-12	8.38E-09	3.05E-05	0.017578
	Migration rate / rural-urban migration	4	9	9	9
	Access to social services	9	9	9	9
	Total Community Vulnerability (TCV₂)	**23**	**36**	**31**	**23**

Fig. 3. State of communities' socio-economic vulnerability.

While Zowayeli is highly vulnerable due to its proximity to the Black Volta River it is able to engage in dry season farming which gives it access to different crop varieties such as fruits and vegetables in addition to tubers and cereals grown during the rainy season. According to Bagayoko (2006), Sandwidi (2007), and Schindler (2009) dry season farming activities are practiced along riverside and inland valleys with crops such as tomatoes, red pepper and onions.

The less vulnerable state of Chietanga and Zowayeli is due to their extensive use of soil improvement technologies such as fertilizer and manure applications. This has been visible through the use of inorganic manure which has led to the establishment of vast mango plantations within those communities.

The application and proper use of inorganic fertilizers and organic manure in parts of northern Ghana are key factors to increase an agricultural yield (Callo-Concha et al., 2012) which in essence enhances food security in the long run. Also, due to the proximity of Zowayeli to the Black Volta River, the community has specialized in the use of flood protection measures. This is evident through the practice of stone bonding to protect their farms from flooding, construction of farm canals to reduce flood intensity in the farms, and farming on ridges and mounds in order to raise the crops above flooding water.

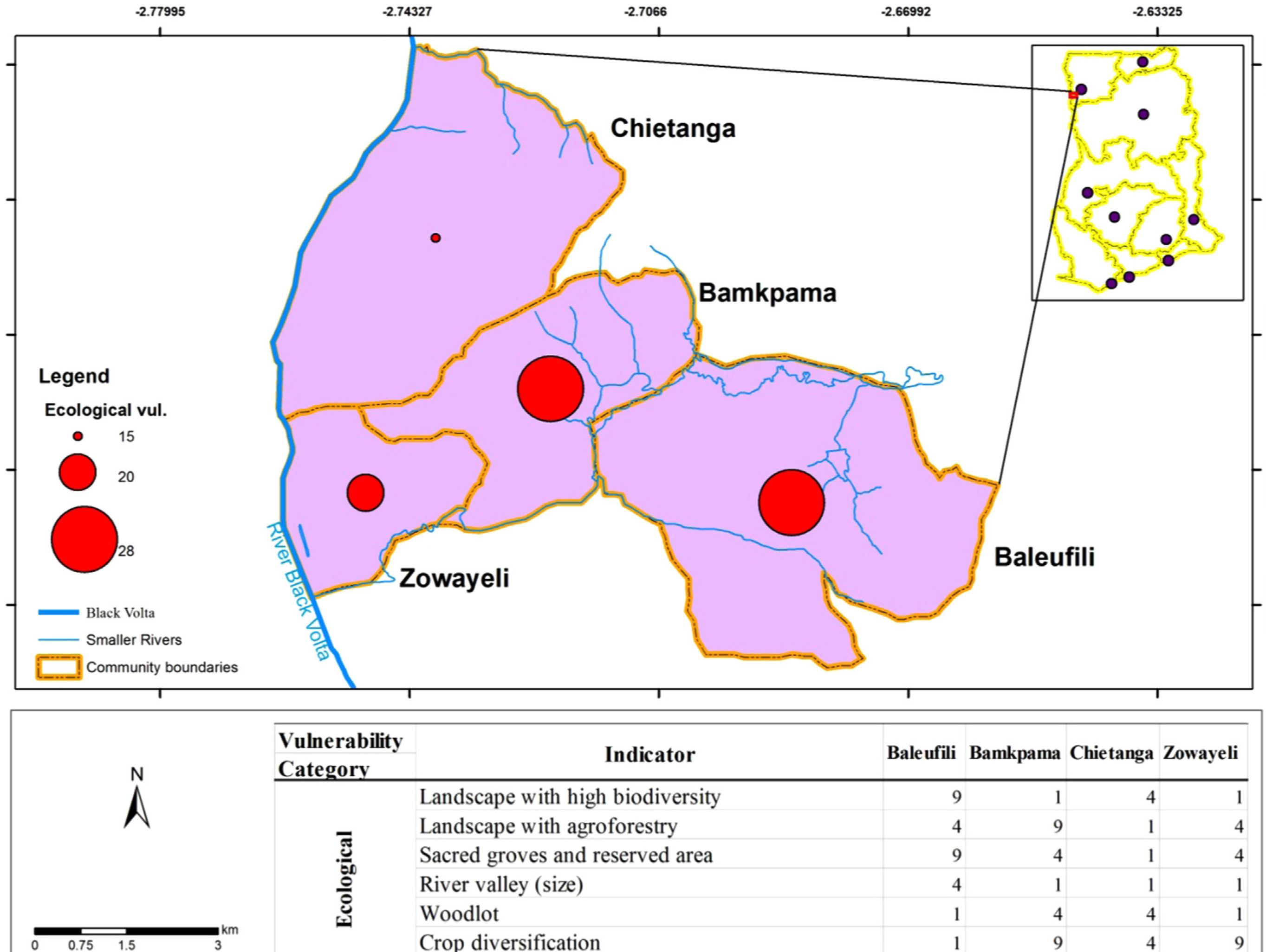
Crops grown in all the study communities are the traditional varieties with little introduction of improved crop variety. However, the high presence of crop diversification and crop rotation evident in most communities is very significant to enhance food availability. A study by Yahaya (2002) in North western Nigeria showed that crop diversification provides household economic security to farmers especially during the dry season, while crop rotation rather than mono-cropping also ensures soil fertility and a means to control pests and weeds on the farms (Raufu and Adetunji, 2012).

5.1.2. State of communities socio-economic vulnerability

In the assessment of socio-economic vulnerability, the TCV score shows that Baleufili came out more resilient followed by Zowayeli, Chietanga and Bamkpama. Baleufili performed better than all communities in the fields of livelihood diversification and level of youth migration.

The low level of youth migration in Baleufili could be attributed to the presence of irrigation facilities as depicted in the engineering vulnerability index. The youth are able to sell their farm produce due to easy access to market centers and major road networks. Furthermore, the large youth population of Baleufili are more knowledgeable on issue of climate change and have relatively high access to early warning systems through radios and mobile phones.

The low socio-economic vulnerability status of Zowayeli is attributed to high livelihood diversification such as fishing and



Vulnerability Category	Indicator	Baleufili	Bamkpama	Chietanga	Zowayeli
Ecological	Landscape with high biodiversity	9	1	4	1
	Landscape with agroforestry	4	9	1	4
	Sacred groves and reserved area	9	4	1	4
	River valley (size)	4	1	1	1
	Woodlot	1	4	4	1
	Crop diversification	1	9	4	9
	Total Community Vulnerability (TCV)	**28**	**28**	**15**	**20**

Fig. 4. State of communities ecological vulnerability.

rearing of different kinds of animals, low population density and low level of vulnerable groups. Knowledge on climate and its related changes such as droughts and floods is low in Zoayeli as these changes have been attributed to the anger of the *gods* towards the community because of new lifestyles and emergence of modern religion mainly Islam and Christianity. Apart from Baleufili, migration was a major issue in all the other communities.

All communities were however highly vulnerable in terms of access to social services. These include access to micro credit schemes, extension services, insurance, remittances and relief items before and after floods or droughts.

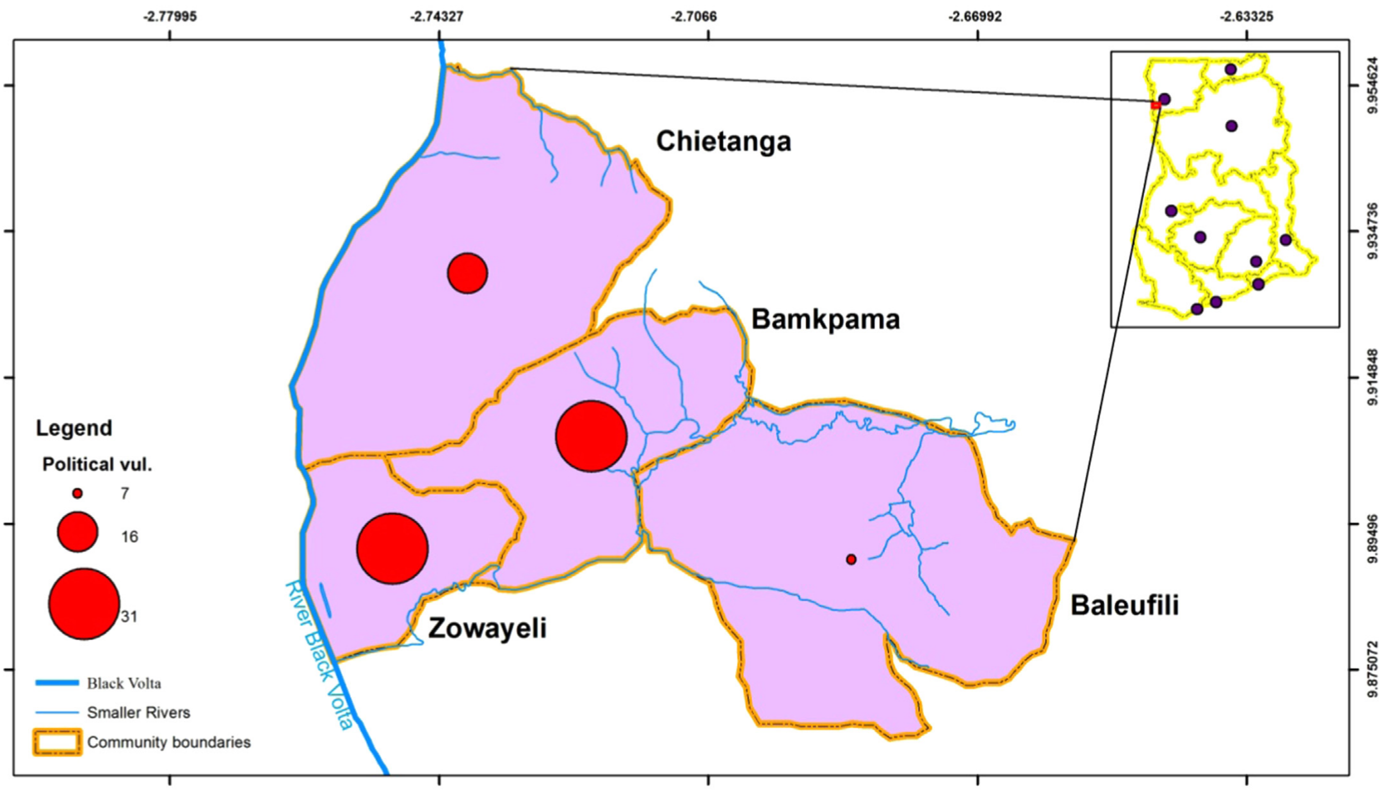
5.1.3. *State of communities ecological vulnerability*

A community's ability to be resilient ecologically depends on its access and wealth in woodlots, river valleys, sacred groves and reserve areas, crop diversification, agroforestry and biodiversity. The abundance of these enables communities to cope, adapt and recover from anthropogenic and natural disasters such as floods and droughts. Absence of these however exposes the community to the dangers and severe impacts of these disasters which do not only cause harm to property but also results in loss of human life.

Chietanga was the least vulnerable community ecologically because it has abundant sacred groves and reserve areas, access to large tracts of river valley for cultivation and the extensive practice of agroforestry. The practice of agroforestry is of great ecological relevance as it helps conserve soil and water, preserve the environment while supplying the needs of farmers and other individuals (Dwivedi, 1992; Adaba, 2011). Vast acres of land in Chietanga, Baleufili and Zowayeli are covered with Shea trees and woodlots which help curb the rate of deforestation of natural vegetation as inhabitants rely on these manmade wood lots for their timber and wood demands. Weber and Hoskins (1983) also identified countries in the Sahel such as Mali, Chad and Senegal as benefiting from these products especially during periods of droughts. On the other hand, agroforestry is rarely practiced in Bamkpama making the community ecologically more vulnerable.

Access to river valleys is important in Northern Ghana since these lowland areas are heterogeneous in morphology, hydrology, vegetation; and often contain good quantity of sandy loam and clay loam soils with good retention capacity (Buri et al., 2012) making them suitable for rice cultivation in rainy seasons and fruits or vegetable in dry seasons. Unlike Baleufili, the relatively large sizes of river valleys in Chietanga, Zowayeli and Bankpama support high crop production and diversification. It must be said that easy access to irrigation facilities in Baleufili in this case enables them to undertake dry season farming which serves as a buffer during the dry season and periods of droughts.

The transect walks in the communities revealed that, across the landscape, Bamkpama and Zowayeli have the most heterogeneous



Vulnerability Category	Indicator	Baleufili	Bamkpama	Chietanga	Zowayeli
Political	Politically influential person	1	9	4	9
	Community Stakeholder Organizations (CBOs)	1	9	4	9
	Assembly member	4	4	4	4
	Local participation in district activities	1	9	4	9
	Total Community Vulnerability (TCV)	**7**	**31**	**16**	**31**

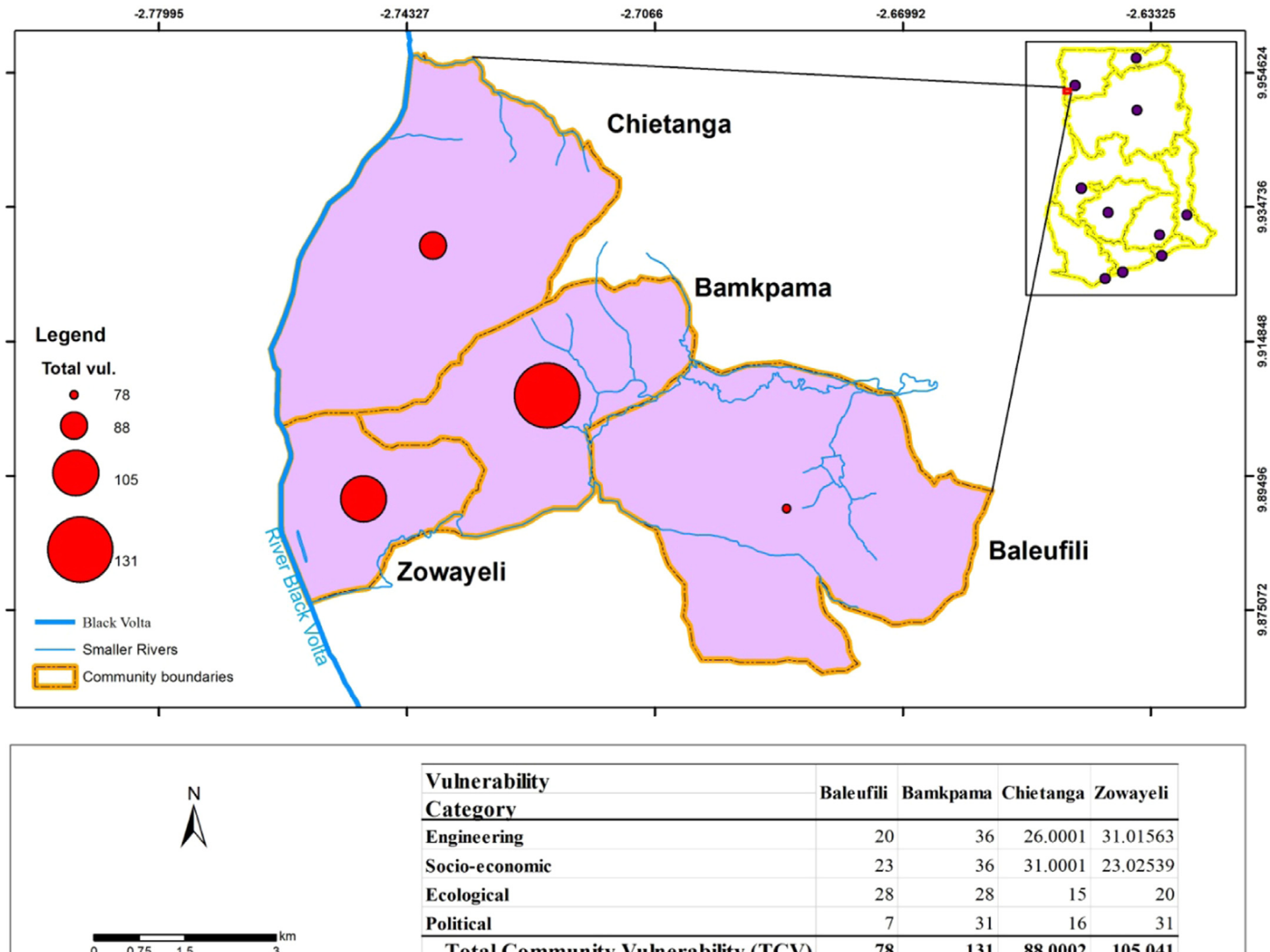
Fig. 5. State of communities political vulnerability.

and biologically diverse landscapes. The presence of sacred groves, reserved area, grazing lands and other landscape features in Zowayeli could reduce their vulnerability to floods and droughts. Chietanga, the least ecologically vulnerable, scored a relatively high vulnerability score for landscape biodiversity and crop diversification. Baleufili recorded low vulnerability in woodlot and crop diversity. However, Bamkpama and Zowayeli were the most vulnerable in relation to crop diversity. Both communities engage less in crop diversity and remain highly prone to pest and disease attack. The presence of irrigation facilities in Baleufili enables the cultivation of crops of different kinds even during periods of floods. Lenssen et al. (2007) and Mertz et al. (2009) identified the importance of crop diversity in regions where climate variability had intensified. Mixed cropping provides a form of food security to farmers as one of the crops is likely to flourish even in periods of harsh weather conditions. Ampong-Nyarko et al. (1994) also identified that crop yields tended to diminish significantly under monocropping system. An experiment conducted reveals a 28% reduction in sorghum yields under monocropping compared to a 15% reduction during intercropping due to insect pest attack. For instance, intercropping carrots with onions reduced carrot fly, *Psila rosae* attack on carrots and *Thrips tabaci Lind* attacks on onion than in monocropping (Coaker, 1984).

Traditional and social norms relating to the use and preservation of biodiversity have been keenly practiced in rural communities such as those in Wa West. Religion often plays a major role in determining communities' involvement in rituals performed in sacred groves and reserved lands. Bhagwat and Rutte (2006) identified the important role of religious beliefs and rituals in conserving biodiversity through the provision of ethical and social models for living in harmony with nature though these have in recent times been treated with disdain. For instance, due to the large Muslim population in Baleufili, conservation of scared groves and reserve areas is minimal. Muslim communities do not share in the belief on scared groves and thus places less importance on them. This makes Baleufili ecologically vulnerable in terms of biodiversity conservation.

5.1.4. State of communities political vulnerability

Baleufili's least politically vulnerable state can largely be attributed to the influential and active role played by the community chief within and outside the community as well as the existence of a diverse stakeholder groups such as farmer-based organizations, women's groups, disable persons association and representatives of the Savannah Accelerated Development Authority (SADA). Chietanga's position as the second politically least vulnerable during periods of flood can be credited to the activeness of the community's chief and assemblyman.



Vulnerability Category	Baleufili	Bamkpama	Chietanga	Zowayeli
Engineering	20	36	26.0001	31.01563
Socio-economic	23	36	31.0001	23.02539
Ecological	28	28	15	20
Political	7	31	16	31
Total Community Vulnerability (TCV)	**78**	**131**	**88.0002**	**105.041**

Fig. 6. Summary of Total Community Vulnerability (TCV).

Respondents in both Baleufili and Chietanga credit their assemblyman and village chief for helping in providing access to agricultural inputs and other livelihood assets from external sources. Baleufili and Chietanga's political capital could have played a significant role in their access to dams and management of irrigation facilities as well as improved crop varieties. As some studies have shown a politically active and influential community stands a better chance of organizing and mobilizing effective relief in times of floods and its related disasters (Fraser et al., 2011).

The high political vulnerability status of Zowayeli and Bamkpama reflects the lack of active engagements in political activities and assets at household level. They remain more vulnerable and less prepared to deal with disaster events especially floods that might require external assistance. Sallu et al. (2010) examined semi-arid rural households in Botswana and found that community's political wherewithal can be an influential factor in addressing annual droughts and floods events. The fact that both villages are dominantly settlers could also explain their low political capitality as they often report to the chief of Baluefili on most issues.

5.2. *Tailoring intervention approaches based on community vulnerability assessment*

The use of vulnerability indicators based on the four vulnerability index categories has revealed variations in the composite as well as individual performance of communities in each vulnerability index category. These variations provide important indication of the cumulative vulnerability strength of communities affected by the same external influence. Giving the score of each community under individual vulnerability index categories as well as the composite category, effective and target specific interventions options could be provided to address the specific needs of communities as a way of enhancing their coping and adaptive capacity to disasters. Thus, the tool provides an effective decision support framework under conditions of limited resources in the context of Northern Ghana.

Baleufili community emerged as the least vulnerable community based on the composite vulnerability indices scoring 78. However, a closer look at the indicators shows that it scored very high in ecological vulnerability. Thus for the purpose of prioritizing an effective resource utilization, more efforts could be channeled to reduce the ecological vulnerability of Baleufili. By building on its strengths in community mobilization and effective political leadership; afforestation and reafforestation of degraded areas in Baleufili could be carried out. This includes tree planting projects involving tree species that can be used for both fuel wood and fodder for feeding farm animals. In essence, total community vulnerability assessment (TCVA) framework specifically offers the opportunity to strengthen existing social groups in ways that will tailor their activities along the weakest areas base on their indicator scores. Similarly, best practices that can be upscaled among communities are easily identified using the TCVA framework.

Chietanga, the second least vulnerable community scored a TCV of 88. Moderately, Chietanga performed well in all the indicator variables. However, the key to Chietanga's relatively less vulnerable state could be attributed to its landscape resource endowment and effective political leadership. Consequently, conserving Chietanga's ecological landscape and resource endowments could be important for long term sustainable response to increasing disaster threats. This could involve building on its politically influential community leadership and support systems in the management of its resources. The two most vulnerable communities; Zowayeli and Bamkpama had TCV scores of 105 and 131 respectively. Both communities generally scored high on the total vulnerability of all four vulnerability index categories making them more vulnerable to flood related disasters and thereby needing an all-encompassing support to reduce their vulnerability.

We recommend the use of measures such as local flood management plan under communities' ownership to quantifiably reduce their level of risk to floods. This could involve both short and long term responses that aim to build the community's capacity to manage flood defense locally by putting in place local response arrangements that helps to address risks identified in the TCVA framework indices. Short term measures could involve immediate adoption of technologies to strengthen existing houses from flood inundation, erosion management control in farms, and early warning system to warn communities against impending floods. On the other hand, long term measures could involve populating the landscape with diverse tree species and building financial resilience of those at risk, particularly lower income or socially vulnerable groups. This could involve working with local farm input dealers and micro-finance agencies to develop approaches such as crop insurance, use of flood tolerant crop production methods and product pooling of farm produce for bigger markets.

6. Conclusions

This study has presented an in-depth analysis of community level assessment of vulnerability to climatological related disasters; flood. By developing variables under the four vulnerability index categories, this study has provided a practical and analytical framework for assessing the vulnerability of communities affected by the same external influence such as flood. The individual and composite score of the vulnerability indicators in each community has enabled a classification of the study communities along a vulnerability scale depending on how their total vulnerability turns out. Drawing from the sustainable livelihoods framework, the study developed an analytical framework of the different shades of interaction that occur in a typical community setting between assets, tools or opportunities available in the community to produce outcomes that are then tested on the vulnerability scale to arrive at level of vulnerability to floods for each community. The analytical tool factored in the complex mix of interactions and relations between and within the indicators captured under each of the vulnerability index categories and the consequent contribution of the total score for each of the indicators.

While we do not claim the indicator variables used under each vulnerability index category are exhaustive and mutually exclusive, our selection is grounded in specific local peculiarities evolving out of extensive engagement with district and community stakeholders as well as expert consultation meetings and discussions. For instance, identifying a variable as having a direct or direct influence depends on the locality under study. As such we believe that our approach could serve as a model for assessing the vulnerability of other communities under similar external influence with modifications to reflect local dynamics and contexts. The process of vulnerability indicator development which involved a series of iterative steps (Antwi et al. 2014) could serve as a useful medium of communication and knowledge sharing between scientist and local people.

Based on the empirical outcomes of this study, we can conclusively reveal that, the state of a community's vulnerability to flood is a composite effect of the ecological, socio-economic, engineering and political indices which act independently or interconnected. By using the TCV scores of each community along the vulnerability indices, the study thus reveal where interventions options could be channeled most effectively to enhance the capacity of flood vulnerable communities in savanna agro-ecological zone of Northern Ghana in order to produce optimum benefit.

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